Art. III.—*On certain Conglomerates near Sydenham.*

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(With Plate IX.).

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Among the older rocks exposed along the deep valleys of the Saltwater River and Deep Creek, across the Keilor Plains, there occur certain conglomerates. Apart from the rarity of conglomerates among these rocks, these present certain features of interest.

This portion of the course of the above-mentioned streams is within the area mapped in Quarter-sheet 7 S.E., extending through 2 S.W. into 1 N.W.

The positions of the conglomerates are denoted by the numbers 1 to 7 on the accompanying map. Of these, Nos. 1 and 3 are unnoticed on the Quarter-sheets, Nos. 5 and 6 are indicated by the symbol "C3," but I failed to detect them when going along those parts of the valleys. No. 7 I have only seen on the river bank at the place at which the number is placed, but it is shown on the Quarter-sheet as far north and south as the crosses on the locality map.

Description of the Observed Conglomerates.

The locality 1 is about a mile and a half from Sydenham Railway Station, and close to the fifteenth milepost on the Mount Alexander Road. The right bank of the Saltwater on this bend rises in a steep cliff. At the western end of this cliff are mudstones and sandstones of ordinary character dipping easterly at 70° to vertical or slightly overturned. These are succeeded by mudstones with pebbles scattered through them in various positions, isolated, or in patches, or somewhat in bands. The pebbles are well-worn, but frequently flat-sided, some present glaciated shapes, and, on a few, obscure striations are present. They range in size up to about six inches, and consist of quartz, quartzite, porcellanite, and quartz-porphyry. These pebbly mudstones have a thickness of about seventeen feet near the water's edge. The matrix is exceptionally somewhat sandy. They are followed by a heavy conglomerate of pebbles of similar character to those in the mudstones, but reaching larger sizes, nearly a foot in diameter, and a few additional rocks were observed, including a greisen.

The pebbles are thickly crowded together, and in various positions, the spaces between large material filled with smaller, and the small quantity of fine material is mainly sandy. The junction with the underlying pebbly mudstones is very uneven; the conglomerate is about 15 feet thick at the water's edge, but contemporaneous erosion has cut away the mudstones higher up the bank and allows the conglomerate to thicken to about 22 feet. In the upper part of the conglomerate there occur two irregular bands of sandstone about 9 inches thick and with few pebbles in them.

The upper surface of the conglomerate is fairly even and is succeeded by a series of pebbly mudstones, similar to those below, for about 40 feet. Then follows an alternation of thin sandstone beds and mudstones, both free from pebbles for about 24 feet. Another band of about 4 feet in thickness and containing pebbles then occurs. The matrix is mainly mudstone but it contains a discontinuous bed of fine sandstone, which, at one place, is folded back on itself, and at another disturbed from its position parallel to the beds. In the upper part of the mudstone and above this sandstone is a band of coarse grit. The next bed following is a sandstone free from pebbles and the pebbles were not observed further at this place.

The series may be tabulated thus:—

Uppermost, eastern end:

Mudstone, with pebbles, and grit band and fine sandstone bed disturbed -	4 feet
Alternating mudstones and sandstones, without pebbles - - - -	24 ,,
Pebbly mudstones - - - - -	40 ,,
Heavy conglomerate - - - -	15 to 22 ,,
Pebbly mudstones - - - - -	17 to 10 ,,
Total	100 feet.

These conglomerates are clearly interbedded with the ordinary Palaeozoic rocks. They are jointed, so much so, that it is difficult to extract pebbles whole. Joint planes can be traced through the pebbly mudstones and conglomerate, and on one of these a thin vein of quartz has since formed. This quartz vein is most easily seen in the pebbles and can be clearly seen crossing older quartz pebbles.

Crumpling in the lamination of the finer beds was noticed, but they are not often visibly laminated. At places a pebble is indented by a neighbouring pebble.

Locality No. 2 is some little distance down the river just before the basalt forms the river bed. The conglomerates are here exposed in a low bank and on the shelving surface of rock near the water and liable to be covered. It is marked on the Quarter-sheet. A conglomerate bed, about 15 feet in thickness, contains pebbles similar in shape and material to the others described, the pebbles reaching a size of about 6 inches. Below it is a patch of pebbles at a distance of about 2 feet. About 30 feet further east (higher in the beds) a band occurs of pebbly beds 2 feet 9 inches, conglomerate 2 feet 3 inches, pebbly beds 2 feet, these layers merging into one another. The matrix of the pebbly beds is here more sandy. The pebbles reach to about 9 inches diameter.

Locality No. 3, on the right bank of the Deep Creek a little above the junction. Here are scattered pebbles, some flat faced, in a compact mudstone matrix. The whole thickness seen was about 8 feet. In it is a band of 7 inches of sandstone without pebbles. Its strike, if continued, would take the beds west of the locality 5.

Locality No. 4, close to the granite in Deep Creek. All the rocks are much indurated to a hardness comparable with the pebbles and on old surfaces pebbles seldom stand out and are not easily noticed. The hardness and splintery character of the altered rock makes examination difficult. Some of the pebbles are flat sided; the largest pebble noticed was of quartz about 8 inches diameter. The bed observed had a thickness of about 10 feet, it is close to a large granite dyke. Quartzite with pebbles and a rock, which might represent the pebbly mudstones, are also present here, as blocks may be seen in the creek. The general character, so far as was seen, was similar to what might be expected from material like that at locality No. 1, altered at the granite contact. The general dip here is easterly at about 60°.

At localities 5 and 6 I did not see the conglomerate.

At locality 7, conglomerate is seen on the right bank of the Saltwater north of Keilor township. The pebbles, to about 10 inches in size, are mainly quartz and quartzite, similar to those at No. 1, in a matrix mostly sandy, but I did not notice any pebbly mudstones. The northerly extension marked on the quarter sheet is mostly under an alluvial flat. About the southern end also little rock is exposed. At the point where they were observed the dip is about 50° westerly and the strike east of north. The thickness exposed is about 10 feet. The beds immediately below are mudstones without pebbles and above sandstone without pebbles and again a thin conglomerate bed.

Glacial Origin of the Pebbly Beds.

The manner of occurence and distribution of the pebbles through the mudstones suggests at once a glacial transport. The pebbles are of various sizes and in various positions and are embedded in and scattered through a matrix which, even when sandy, would have been completely removed by any current competent to move the pebbles. Only exceptionally are the pebbles so crowded that fine material could have lodged among them and this crowding is only in patches. The general aspect, expect as to inclination, is very similar to parts of the glacial deposits of Bacchus Marsh and elsewhere. They agree also very closely with the description recently given by Mr. Howchin[1] of certain supposed Cambrian glacial beds near Adelaide, only that here the pebbles do not reach anything near the same dimensions.

Glaciated pebbles and some striated occur, associated indeed with many rounded ones, and an examination of the matrix in the lower pebbly mudstones at locality 1 shows that it is clear and sharp, rather abraded than weathered material. Some of the pebbles show crystals of pyrite ground down but not decomposed. While no other explanation except glacial transport seems practicable for the general characters of the deposit, the relations to the beds above and below preclude any idea of accumulation

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1 Trans. Royal Society S.A., vol. xxv., pt. i., 1901.

on land. The mudstones containing the pebbles and sandstones between them at locality 1, and as far as noticed elsewhere, are essentially part of a continuous series extending both above and below them, under generally similar conditions, undoubtedly marine. We are therefore limited to transport by floating ice, not by land ice. With this agrees the disturbance of the fine sandstone near the top of the series at locality No. 1, which would be ascribable to stranding of the floating ice. The disturbance is quite different from that which I have before ascribed to differences of rigidity under folding in the Ordovician rocks.[1]

While icebergs from extensive ice sheets and glaciers often carry little foreign material compared with their bulk, the case is essentially different with shore ice and river ice. Nor are the glaciated stones sufficiently numerous or distinct to regard the ice as the only agent operating.

The following description of the Yukon by Mr. I. C. Russell seems to fulfil the conditions of this case.

The Yukon "freezes deeply during the winter and the ice near its borders, especially when it is broad and shallow, rests on the bottom and has large quantities of stone and boulders attached to it. All except the largest of the tributory streams freeze to the bottom and also furnish vast quantities of pebbles for ice transportation. When the rivers break up in the spring, the ice with its loads of stone is floated down stream, and melting, as it goes, distributes pebbles and boulders over the bottom of the river and in places where at other times fine sediment is deposited. In this way it is conceivable that a clay filled with boulders might be formed which would simulate true boulder clay in many ways. Certain boulder clays along the Yukon and the Lewes are described elsewhere in this paper, which, as there stated, may have been formed in the manner here suggested."[2]

Now, it will be evident that the formation of such a deposit resembling boulder clay will not be limited to the course of the river but may occur as far as the ice can reach in floating out to sea and that shore ice may behave in just the same manner. The

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[1] Proc. Royal Society Vic., vol. xiv., pt. ii n.s.

[2] Bull. Geol. Soc. Amer., vol. i., 1890.

materials carried will be firstly river gravels or coast shingle as the case may be, but among those from the river glaciated stones may occur in two ways. It is noted on the Yukon, by the same writer, that stones embedded in the clay on the banks become ground on one side by the stranding of river ice, especially in spring floods while ice barriers still exist in the river. The material also in the river may itself be largely derived form glaciers, as the nature of the mudstone matrix would suggest in this case.

The pebbles will naturally be more numerous in mudstones because first the mudstone being more slowly formed than the sandstone as a rule, more ice is likely to float across it while a given thickness is deposited, and, secondly, because the current being more gentle more of the ice is melted as it passes over it at a slow speed. No indentation need be seen on the beds even if they are laminated, for the stones may sink gently with ice still attached.

A minor arrangement of the pebbles as continuous bands may readily occur by the drift ice being more abundant at certain times or a tendency of the ice to accumulate at certain places.

The character of the pebbly mudstones and sandstones is just what might be expected off a coast along which the climate was such that considerable rivers could freeze to the bottom in winter and much shore ice could be formed. Such a condition may be associated with neighbouring general glaciation as at present in Alaska, where glaciers occur south of the Yukon. The moderate size of the largest boulders also favours this view.

The formation of the heavy conglomerate under such conditions may be due to ordinary current transport, and the erosion of the underlying mudstones favours this view. The stranding of ice would however assist, when by gradual melting at one place, a heterogeneous mass of gravel of all sorts and sizes would readily accumulate, and the stranding and the rocking of the stranded masses might also have caused the erosion.

The severe climatic conditions might also contribute to the complete break in the fossil fauna which seems to occur about this horizon.

These evidences of glacial action occur at the localities Nos. 1, 2, 3 and 4, but I did not notice them at No. 7 (Keilor).

Source of the Material.

The materials of the pebbles require for their supply a land surface of sedimentary rocks already invaded and altered by igneous rocks and with volcanic rocks also exposed. The altered sedimentary rocks are represented by the quartzite, porcellanite and lydianite; the igneous by the quartz porphyry, greisen, a peculiar fine graphic granite, and a vescular fragment. Vein quartz also occurs.

The land area of Heathcotian rocks, as recently described by Dr. Gregory[1] may have provided these materials. The position of the beds is in the gap existing in Upper Ordovician times in the ridge southward from Lancefield ranges.

Age of the Conglomerates.

In a former paper referring to these conglomerates, I stated that their Ordovician age was uncertain.

The Quarter-sheet appears to show all the palaeozoic rock in 7. S.E. as "Lower Silurian" a number of fossils being recorded at the north-west corner of the sheet. As the whole of the bedrock exposed along the Saltwater in 2. S.W. is mapped as "Upper Silurian" the question of the actual contact appears to be avoided. There is a fossil locality Ba60 marked on the Deep Creek (close to locality 5) of which I have found no mention in published reports, but it would support, no doubt, the extension of the "Lower Silurian" colouring to the Deep Creek, which is near the east side of the sheet. On a copy of 7 S.E., at the Melbourne Public Library, I found that the Lower Silurian colouring stops a short distance before the edge of the Quarter-sheet (at the line J on the locality map), a small space being left uncoloured. In all other copies I remember to have seen the "Lower Silurian" colouring extends to the edge of the sheet.

On visiting the locality, this part of the river channel looked at first very unpromising for rock exposures, alluvial material being abundant; but the river being low, a small outcrop of rock was found exposed on the right bank close to the water within the area uncoloured on the Public Library map. A rough observation of strike and dip gave strike about N. 30° W. dip

1 Proc. Royal Society Vic., vol. xv., pt. ii., n.s.

easterly at 47°. About 15 chains to the N.W. the beds exposed on a steep bank appear to strike N. 5° W. and are nearly vertical. Directly over this, in a track cut up the hillside, the apparent dip is only 35° easterly, but this may be due to slipping on the steep hillside. Higher up stream a good exposure gave a strike N. 10°, W. and dip about 70° easterly, not westerly, as shown here on the Quarter-sheet, and, from here up, high dips are the rule. Down stream in sheet 2 S.W. there is at first an easterly dip about 45° becoming much less further on, and continuing moderate as far as Keilor. The position then at which the colouring ends on the Public Library copy is the boundary between the general high dips on the north-west and the moderate or low dips on the south-east. With the river at a higher level this boundary might easily have been placed further east at the edge of the quarter sheet.

About a mile to the north west (H on map) a strike N. 18° W. dip about 30° easterly occurs in a low cliff, but near the water's edge the dip is 70° easterly and the strike different, considerably nearer to north. Between the places of these observations there is a fault to which the beds turn from both sides, but the observations were taken clear of all noticeable turning.

The age of the conglomerates in 7. S.E. may then be regarded as Upper Ordovician probably mostly in slightly lower beds than the fossils of Ba60. Exact comparison of positions of different beds would be affected by faults which are probably common.

The conglomerate at Keilor is close to localities from which "Upper Silurian" fossils are recorded. Going north from locality 7 the strata exposed form an anticline with a strong northerly pitch, dips and strike being apparently very variable: at one place strike N. 82° E., dip 35° northerly. The beds exposed to the north are therefore newer, and the Keilor conglomerate is probably near the lowest beds exposed in the Silurian area within the limits of the area under consideration.

Two explanations of the relations of the two series might be offered.

The moderate dips and irregular strikes of the upper beds may be due to their occupying a crumpled syncline, of which the older beds to the west form one flank, with a steeper, more regular, dip and strike. This receives some support from the fact that some miles higher up the Deep Creek high dips are prevalent in areas mapped as "Upper Silurian."

The alternative is that we have here two distinct series, one of which dips less steeply than the other and rests unconformably on it (at J an unconformity could be avoided by a faulted junction such as occurs at H). That they are two independent series is more likely, for the relations of the dip and strike of the two series at J and H are very similar and agree well with what would occur on a parallel anticline to that of Keilor, also with a northerly pitch, whereas in irregular minor crumpling in a syncline such correspondence seems unlikely. I have already mentioned that I did not notice glacial evidences at Keilor. The material seemed to have been derived from the same land surface as the other conglomerates, not necessarily under the same conditions.

I am not aware of any previous notice of glacial conditions in Ordovician time in Australia. An occurrence of probably glacial origin is described by Mr. W. Howchin, F.G.S., in Kangaroo Island,[5] which is older than the prevailing glacial series there, but, though its age is uncertain, it does not seem to be referable to quite as early an age as this.

The series more recently described by him near Adelaide, and already referred to, is regarded as Cambrian on the general weight of the evidence.

There are a number of Victorian localities at which the existence of glacial rocks has been noticed without much evidence as to the relations to other beds. No doubt the majority of these belong to the Bacchus Marsh series, but the existence of others of this series is also possible.

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5 Tran. Roy. Soc. S.A., vol. xxiii., pt. ii., 1899.